CLAIMS

What is claimed is:

1. A hardware-adaptable data visualization tool for use in visualizing data from a data source, comprising:

a) a data source module, responsive to data source input files indicating information about a geometry to be visualized, for providing as a stream of data to be interpreted a numerical data set representing aspects of the data; and

b) a viewer module, for providing the data source input files, responsive to the numerical data set for providing a view of the numerical data set helpful to a user in interpreting the numerical data set;

wherein the viewer module in turn comprises a plurality of viewer component modules, and wherein the source module and the viewer component modules are compiled and linked together into one or more executable files depending on factors including at least either the performance capabilities of a predetermined target host or hosts or the desired utility of the executable files, the component modules having programming interfaces that are substantially independent of the predetermined target host or hosts, whereby different visualization tools are able to be provided all from the same data source module and viewer component modules, the different visualization tools being tailored to different performance capabilities of different target hosts.

2. A hardware-adaptable data visualization tool as claimed in claim 1, wherein the viewer component modules comprise:

a) a geometry manager, responsive to geometry information describing the boundaries of a geometry corresponding to a

region being viewed and responsive to changes in the geometry information and associated display characteristics, for providing a representation of the boundaries of the region being viewed, and for providing the data source input files including information about the geometry;

b) an interface module, serving as the means by which a user of the data visualization tool requests views or requests to view objects, responsive to user tool controls and inputs, for providing changes to the geometry and associated display characteristics, for providing display characteristics associated with graphic representations of visualization objects, for providing flight plans indicating information for providing a view of the numerical data set, and also responsive to summary data, and further for providing graphics output of the summary data;

c) an automation/scripting module, for maintaining flight plans or other standardized instructions for viewing the numerical data set, responsive to the flight plans, for providing changes to display characteristics associated with the flight plans;

d) a visualization object client/graphics module, for retrieving, storing, and displaying dynamic visualization objects that represent information in the numerical data set, responsive to changes to display characteristics, responsive to and for providing summary numerical data, and responsive to visualization data, and for providing graphics representations of visualization objects;

e) a visualization object server, for generating graphical objects, responsive then to data for generating graphical objects, for providing the generated graphical objects;

f) an auxiliary calculation module set, for translating the numerical data set after standard formatting into data for visualization, for providing the data for visualization; and

g) a query library module, for converting different data source program data structures into a standard application programming interface and so allowing visualization of data from data source programs that output data in different formats, responsive to the numerical data set, for providing the numerical data set according to standard formatting;

wherein the data source module is selected from the group consisting of calculatory data source modules and non-calculatory data source modules.

3. A hardware-adaptable data visualization tool as claimed in claim 2, wherein the data source module is a computational fluid dynamics (CFD) module.

4. A hardware-adaptable data visualization tool as claimed in claim 2, wherein all of the viewer component modules are compiled and linked together into a single executable file and the data source module is compiled into a separate executable file, thereby providing a data visualization tool in which computing equipment most suitable for computation can be used as a host of the data source module, and computing equipment most suitable for providing a view helpful in interpreting the data stream provided by the data source module can be used as a host of the viewer.

5. A hardware-adaptable data visualization tool as claimed in claim 2, wherein the data source module is linked together into a single executable file, the query module, the auxiliary

calculational module set, and the visualization object server module are compiled and linked together into a single executable file, and the other component modules of the viewer module are compiled and linked together into a single executable file, thereby a data visualization tool that is distributed across up to three different target hosts, communicating via a network and/or a file system.

6. A hardware-adaptable data visualization tool as claimed in claim 2, wherein the data source module, the auxiliary calculational module set, such as the tracking module, and the query module are compiled and linked together into one executable file, thereby making possible the use of the tracking module to generate information on spray trajectories or other similar information generated by an other auxiliary calculational module and used as a basis for source term inputs to the data source module during execution, and wherein the remaining modules, however compiled and linked, form the viewer.

7. A hardware-adaptable data visualization tool as claimed in claim 2, wherein all of the viewer component modules and the data source module are compiled and linked together into a single executable file, thereby providing a viewer with a capability of examining intermediate results of the data source module as it performs a calculation and steering the calculation of the data source module.

8. A hardware-adaptable data visualization tool as claimed in claim 2, wherein the data source module, the query library module, the auxiliary calculational module set, and the visualization object server are all compiled and linked together into one executable file, and the other modules, the principal

viewer modules, are all compiled and linked together into a second executable file, and wherein the viewer is connected to the data source module via a network link, and so is able to examine intermediate results of the data source module as it performs a calculation and steer the calculation as the data source module is performing the calculation.

9. A hardware-adaptable data visualization tool as claimed in claim 1, wherein the tool is used for the analysis and engineering design of a fluid dynamic system, wherein the data for visualization provided by the tracking module is particle trajectory data, and further wherein:

a) the data source module is a computational fluid dynamics (CFD) module, responsive to data on the geometry of the fluid dynamic system, and provides, as a stream of data to be interpreted, a numerical data set representing flow; and

b) the viewer module is responsive to the numerical data set representing flow, and provides the data on the geometry of the fluid dynamic system, and also provides a view of the numerical data set representing flow in an environment, such as a fully immersive environment, that helps a user interpret the numerical data set.

10. A hardware-adaptable data visualization tool as claimed in claim 1, wherein the tool is used for the analysis and engineering design of a fluid dynamic system in which a reacting flow occurs, and further wherein:

a) the data source module is a computational fluid dynamics (CFD) module, responsive to data on the geometry of the fluid dynamic system, and further responsive to data on sources of reacting species being added to the reacting flow, and provides, as a stream of data to be interpreted,

a numerical data set representing flow and other characteristics of the reacting flow; and

b) the viewer module is responsive to the numerical data set representing flow and other characteristics of the reacting flow, and provides the data on the geometry of the fluid dynamic system, and also provides a view of the numerical data set representing flow and other characteristics of the reacting flow in an environment, such as a fully immersive environment, that helps a user interpret the numerical data set.

11. A hardware-adaptable data visualization tool as claimed in claim 1, wherein the tool is for use in designing targeted in-furnace injection systems, such as pollution control systems, for controlling a combustion process, the special features for introducing into the combustion process species that react with the combustion products, and further wherein:

a) the data source module is a computational fluid dynamics (CFD) module, responsive to data on the geometry of the combustion system including the special features, and further responsive to data on sources of the reacting species being added to the combustion process, and provides, as a stream of data to be interpreted, a numerical data set representing flow and other characteristics of the combustion process; and

b) the viewer module is responsive to the numerical data set representing flow and other characteristics of the combustion process, and provides the data on the geometry of the combustion system including the special features, and also provides a view of the numerical data set representing flow and other characteristics of the combustion process in an environment, such as a fully

immersive environment, that helps a user interpret the numerical data set.

12. A hardware-adaptable data visualization tool as claimed in claim 1, wherein the data visualization tool comprises two or more different viewer modules, wherein one viewer module is hosted by a first computer, another viewer module is hosted by a second computer, and so on, and wherein the viewer modules use the same model data.

13. A hardware-adaptable data visualization tool as claimed in claim 1, wherein multiple synchronized dialog boxes are used to prevent data corruption.

14. A hardware-adaptable data visualization tool as claimed in claim 1, wherein separate control dialog boxes and visualization windows are provided.

15. A hardware-adaptable data visualization tool as claimed in claim 2, wherein a strong scripting language is used to provide input to the automation and scripting module for directing real-time visualization.

16. A hardware-adaptable data visualization tool as claimed in claim 1, wherein a script file is used to generate a complex visualization picture.

17. A hardware-adaptable data visualization tool as claimed in claim 1, wherein object structures are provided that can use the same graphics libraries with more than one VR base library, including a CAVElib based application or a VR Juggler based application.

18. A hardware-adaptable data visualization tool as claimed in claim 1, wherein the viewer places multiple graphical representations of particles on a single streamline, allowing the streamline to visually represent more particles than are calculated.

19. A hardware-adaptable data visualization tool as claimed in claim 1, wherein streamlines are colored by time of life.

20. A hardware-adaptable data visualization tool as claimed in claim 1, wherein a programming interface is provided allowing a user to code a color map using one or another function $f(s)$ for mapping a scalar value s to a desired color.

21. A hardware-adaptable data visualization tool as claimed in claim 1, wherein one code section is used to visualize all different types of graphical tracking objects, such as streamlines, injectors, and massed injectors.

22. A hardware-adaptable data visualization tool as claimed in claim 2, wherein each of the modules are implemented according to an object-oriented design so as to allow the viewer to interpret any type of data.

23. A hardware-adaptable data visualization tool as claimed in claim 1, wherein each of the modules are implemented according to an object-oriented design so as to allow the application to interpret different types of cells in a single data source output file.

24. A hardware-adaptable data visualization tool as claimed in

claim 1, wherein each of the modules are implemented according to an object-oriented design so as to allow plugable readers for data sets provided by the data source program.

25. A hardware-adaptable data visualization tool as claimed in claim 1, wherein injector characteristics are definable via a plug-in.

26. A hardware-adaptable data visualization tool as claimed in claim 1, wherein particle plug-ins are used to enable a user to develop different particle characteristics.

27. A hardware-adaptable data visualization tool as claimed in claim 1, wherein contour planes are constructed by sampling points on a regular two-dimensional grid, thereby providing contours that are grid-independent.

28. A hardware-adaptable data visualization tool as claimed in claim 1, wherein the viewer component modules comprise:

a) a data visualization module, responsive to geometry information describing the boundaries of a geometry corresponding to a region being viewed and responsive to changes in the geometry information and associated display characteristics, for providing a representation of the boundaries of the region being viewed, and for providing the data source input files including information about the geometry, and also for retrieving, storing, and displaying dynamic visualization objects that represent information in the numerical data set and so responsive to changes to display characteristics, also responsive to and for providing summary numerical data, and responsive to

visualization data, and for providing graphics representations of visualization objects;

b) an interface system module, an interface module, serving as the means by which a user of the data visualization tool requests views or requests to view objects, responsive to user tool controls and inputs, for providing changes to the geometry and associated display characteristics, for providing display characteristics associated with graphic representations of visualization objects, and also responsive to summary data, and further for providing graphics output of the summary data, also for maintaining flight plans or other standardized instructions for viewing the numerical data set, for providing changes to display characteristics associated with the flight plans;

c) a data interpretation module, for generating graphical objects, responsive to data for generating graphical objects, for providing the generated graphical objects, and also for translating the numerical data set after standard formatting into data for visualization, for providing the data for visualization; and

d) a data translation module, for converting different data source program data structures into a standard application programming interface and so allowing visualization of data from data source programs that output data in different formats, responsive to the numerical data set, for providing the numerical data set according to standard formatting;

wherein the data source module is selected from the group consisting of calculatory data source modules and non-calculatory data source modules.